ASSESSING LOW THERMAL CONDUCTIVITY OF BRICKS WHICH CONTAIN RICE HUSK, CORN COB AND WASTE TEA AS AN ADDITIVE MATERIAL

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Thesis submitted in partial fulfillment of the requirements for the Master's Degree

Fakulti Kejuruteraan Awam Dan Alam Sekitar
Universiti Tun Hussein Onn Malaysia

NOVEMBER 2017

DEDICATION

A million thanks to those who had helped me in finishing this thesis.

To my supportive supervisor, Dr Rafikullah bin Deraman, thank you so much for your guidance, knowledge and so much idea shared throughout this study.

To my beloved parents, En. Mat Saman bin Muktar and Pn. Zaiton binti Mamat, thank you so much for the support, encouragement and motivation for me in finishing my study.

To all my family members, thank you for your support.

To my husband, Hafeez Nadzreen bin Asnawi thank you so much for your support and spirit through my ups and downs in finishing this thesis.

To all my fellow friends, thank you for your support.

ACKNOWLEDGEMENT

بسم الله الرحمن الرحيم

Assalamualaikum W.B.T

Undertaking this Master Degree has been a truly life-changing experience for me and it would not have been possible to do without the support and guidance that I received from many people.

I would first like to thank my supervisor, Dr Rafikullah bin Deraman who had provided guideline, knowledge and advice to me throughout this study. The door to Dr Rafikullah office was always open whenever I ran into a trouble spot or had a question about my research or writing. He consistently allowed this thesis to be my own work, but steered me in the right the direction whenever he thought I needed it.

I gratefully acknowledge the funding received towards my Master Degree from Short Term Grant (U342) through Office for Research, Innovation, Commercialization and Consultancy Management (ORICC) for the financial support.

I am also very grateful to all those who had help me in collecting the materials for this study. Thanks to Kilang Yong Peng Batu Bata Sdn. Bhd. who had gave permission to collect the clay soil. Thanks to Saifulam Agro Farm who had provided the rice husk. Thanks to Kian Heng Lee Sdn. Bhd. who had provided the corn cob. Lastly, thanks to

Puan Ramlah, restaurant owner at Kompleks Niaga Parit Raja who had gave permission for me to collect the waste tea.

I greatly appreciate the support received through the collaborative work undertaken with the Kilang Yong Peng Batu Bata Sdn. Bhd. during this research study – thank you for allowing me to send all the brick samples for firing process.

My thanks also go out to the support I received from the collaborative work I undertook with the Malaysian Palm Oil Board (MPOB) during this research study – thank you for allowing me to send all the brick samples for thermal conductivity testing.

I would also like to thank the UTHM, UPM and UMP laboratory technician who had helped me in laboratory testing for the materials throughout this research study.

I would also like to say a heartfelt thank you to my husband, parents and family for always believing in me and encouraging me to follow my dreams, providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

Thank you.

ABSTRACT

Energy efficient buildings have emerged as a new approach to encourage use of natural resources and reduction of energy requirements. Thermal and mechanical brick properties play an important role in designing modern buildings. Decreasing thermal conductivity is the dominant factor in reducing heat that could be transferred to or from the building. The main objective of this study is to produce low thermal conductivity brick which helps in improving the surface temperature of the building. Malaysia climate which is 30˚C – 34˚C, exceed the thermal comfort of 26˚C. Excessive heat in the buildings causes discomfort to the occupants. Malaysia produce a vast amount of agricultural waste which is 47, 402 dry/kilotonne/year. It will lead to the disposal problem of these waste materials. Recycling rice husk (RH), waste tea (WT) and corn corb (CC) into fired clay brick can improve thermal conductivity of the existing fired clay brick and reduce waste disposal problem. This study was conducted to identify the effects of using RH, WT and CC on the physical, mechanical and thermal properties of fired clay bricks. The percentage of RH, WT and CC used are 2.5%, 5%, 7.5% and 10%. Standard size of fired clay brick are 215 mm x 102.5 mm x 65 mm. Compressed Stabilized Earth Machine (CSEM) with 900-1000 psi pressure was used in producing these bricks. This study focused on the compressive strength, water absorption and thermal conductivity of the fired clay bricks according to the BS 3921: 1985, MS 76: 1972 and ASTM C518 respectively. Results show that the compressive strength value decrease, water absorption increase and thermal conductivity decrease as the percentage of RH, WT and CC used is increased. However, all the result obtained still complies with the standard used. 7.5% RH (chosen from the low thermal conductivity value and have optimum compressive strength) and control brick (CB) was used to build a small masonry wall sized 1m length x 0.215 m width x 1m height. Result indicates that RH small masonry wall recorded low temperature compared to the CB small masonry wall.

Low thermal conductivity bricks can helps in reducing heat absorbed by the bricks and provide better comfort condition to the occupants.

ABSTRAK

Penggunaan tenaga yang cekap dalam bangunan muncul sebagai satu pendekatan baru yang menggalakkan penggunaan sumber semulajadi dan mengurangkan penggunaan tenaga. Ciri – ciri terma dan mekanikal batu bata memainkan peranan penting dalam mereka bentuk bangunan moden. Pengurangan kekonduksian terma adalah faktor utama dalam mengurangkan haba yang boleh dipindahkan ke atau dari sesebuah bangunan. Objektif utama kajian ini adalah untuk menghasilkan batu bata yang mempunyai kekonduksian terma yang rendah yang dapat membantu memperbaiki suhu permukaan sesebuah bangunan. Iklim di Malaysia iaitu 30˚C - 34˚C adalah melebihi suhu selesa iaitu 26˚C. Haba yang berlebihan dalam sebangunan menyebabkan ketidakselesaan kepada pengguna. Malaysia menghasilkan sejumlah besar sisa pertanian iaitu 47, 402 kiloton/tahun. Ia akan membawa kepada masalah pembuangan sisa pertanian ini. Kajian ini dijalankan untuk mengenal pasti kesan menggunakan sekam padi (RH), hampas teh (WT) dan tongkol jagung (CC) ke atas sifat – sifat fizikal, mekanikal dan terma dalam penghasilan bata tanah liat yang dibakar. Peratusan RH, WT dan CC yang digunakan dalam kajian ini adalah 2.5%, 5%, 7.5% dan 10%. Saiz piawai batu bata tanah liat yang dibakar adalah 215 mm x 102.5 mm x 65 mm. *Compressed Earth Stabilized Machine* (CSEM) dengan tekanan 900-1000 psi telah digunakan dalam penghasilan batu bata dalam kajian ini. Kajian ini memberi tumpuan kepada kekuatan mampatan, kadar penyerapan air dan kekonduksian terma batu bata tanah liat yang dibakar berdasarkan BS 3921: 1985, MS 76: 1972 dan ASTM C518. Keputusan kajian menunjukkan apabila peratusan RH, WT and CC meningkat, kekuatan mampatan menurun, kadar penyerapan air meningkat dan kekonduksian terma menurun. Walau bagaimanapun, keputusan yang diperolehi masih mematuhi piawaian yang ditetapkan. 7.5% RH (dipilih daripada nilai kekonduksian terma yang rendah dan mempunyai kekuatan mampatan yang optimum) dan bata kawalan (CB) telah digunakan untuk membina dinding kecil berukuran1m

panjang x 0.215m lebar x 1m tinggi. Keputusan menunjukkan bahawa dinding RH mencatatkan suhu yang rendah berbanding dinding CB. Bata yang mempunyai nilai kekonduksian terma yang rendah dapat membantu mengurangkan penyerapan haba dan meningkatkan keselesaan kepada pengguna.

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CHAPTER 1

INTRODUCTION

1.1 Research background

Bricks have been a major construction and building material for a long time. The dried-clay bricks were used for the first time in 8000 BC and the fired clay bricks were used as early as 4500 BC. The worldwide annual production of bricks is currently about 1391 billion units and the demand for bricks are expected to be continuously rising (Arshad and Pawade, 2014).

Energy efficient buildings have emerged as a new approach to encourage using natural resources and reduce the energy requirements to maintain indoor comfortable conditions (Thormark, 2006). One of the main advantages of the thermal conductivity reduction is that a thin wall of low thermal conductivity can replace thick wall where both may reduce heat that could be transmitted through them. The existence of voids inside the bricks makes an advantage of a higher strength/weight ratio, better tensile strain capacity and lower thermal expansion, as well as superior heat and sound insulation characteristics (Shibib *et al*, 2013).

Thermal and mechanical brick properties play an important role in designing modern buildings. One of the main factors that affects cooling load in air-conditioning space are the thermal properties of building material such as thermal conductivity and density. A building material with proper physical and mechanical characteristics as well as thermal properties in respect to radiation will contribute towards controlling heat transmission through it. Decreasing thermal conductivity is the dominate factor in reducing heat that could be transferred to or from the building (Shibib *et al*., 2013).

Different types and thicknesses of walls will have a bearing on the thermal resistance of the building envelope (Elias *et al*, 2006). Hence, the utilization of low thermal conductivity building materials is important to decrease heat gain through the envelope into the building in tropical climate country like Malaysia. Malaysia climate which is 30˚C – 34˚C (Azzmi and Jamaludin, 2014), exceed the thermal comfort of 26˚C. Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment when the body functions well (Naji *et al*, 2017).

Malaysia produces a vast amount of agricultural waste which is 47,402 dry kiloton/year (Goh *et al*, 2010). The agricultural industry plays a significant role in the overall economic growth in the world (Kamisan and Nek Kamal, 2009). Globally, 1.2 billion tonnes of agricultural waste is produced in a year. In Malaysia, 1.44 million tonnes of agricultural waste is disposed into landfills annually. It is estimated that 15% of the total waste generation consists of agro waste.

Agricultural waste generation in Malaysia was 0.228 (kg/cap/day) in 2014 which is projected to reach 0.285(kg/cap/day) by 2025 (Agamuthu, 2014). The generation of agricultural waste is anticipated to be on the rise and if not be able to efficiently dispose it there would be a great escalation in social and environmental problems. Even though agro-based industry generates various types of waste, these wastes are mostly composed of organic matter which has high potential to be converted into value added products.

In this study, utilization of rice husk (RH), corn cob (CC) and waste tea (WT) to the building material which is brick was invented in order to gain low thermal conductivity.

1.2 Problem statement

Thermal conductivity of a building material is an important parameter as it effect to the energy consumption of the building. Consequently, the thermal insulation properties of building materials such as traditional clay bricks are of paramount importance (Nonthaphong, 2013). In tropical climates, more heat is received because Malaysia is located at the equatorial region which the weather is warm and humid all year. Building envelopes such as walls, roofs and windows exposed to the sun, admitting heat and leading to an increase air temperature inside the building. Excessive heat in buildings

causes discomfort to the occupants (Elias-Ozkan *et al*., 2006). Therefore, selecting the proper thermal properties of a building envelope play a major role in determining the energy consumption patterns and comfort conditions in enclosed spaces.

Also, the management of waste materials is a problem worldwide. In the developing countries, waste management is becoming an acute problem as urbanization. Besides, economic development will increase and lead to a larger quantities of waste materials requiring management in these countries. In Asia, the management of waste materials requires immediate attention especially in countries like Malaysia, China and South Korea which have been categorized as emerging industrilalized countries (Lau, 2004).

Due to the lack of research on evaluate the thermal performance brick, this research considered the use of these waste materials as an additive in improving the thermal performance on existing brick. Recycling of RH, WT and CC in brick manufacturing as building materials appear to be viable solution not only to such pollution problem, but also to the problem in economic design of buildings. Besides, it is also one promising alternative to meeting the challenges of disposing agricultural waste, achieving the sustainable end product. In addition, RH, WT and CC are such a potential material for energy-saving building materials to improve thermal conductivity brick and reduce heat transfer into the building.

1.3 Objectives of the study

The aim of this study is to produce low thermal conductivity of fired clay brick containing RH, WT and CC. Therefore, it is important to investigate the effect of adding these fibers in the fired clay brick. A comprehensive experimental work has to be designed in order to determine and examine the performance of the bricks. Therefore, to achieve the aim, the study identifies three main objectives which are:

1) To identify the material characterization of clay soil, cement, RH, WT and CC.
2) To investigate the physical and mechanical properties of control brick, RH brick, WT brick and CC brick.

3) To evaluate the surface temperature of small masonry wall model built up from agricultural waste brick and control brick.

1.4 Scope of the study

This study focused on the production of bricks by using RH, WT and CC. In addition, laboratory tests are very important in determining the appropriateness of the use of the RH, WT and CC over fired clay brick. Laboratory tests that are carried out in this study are sieve analysis test, Atterberg limit test, specific gravity test, jar test, compaction test, x-ray fluorescent (XRF) test, scanning electron microscopy (SEM) test, compressive strength test, water absorption test, thermal conductivity test and surface temperature performing test. The percentage of RH, WT and CC used are 0%, 2.5%, 5%, 7.5% and 10%. Then, the study was followed by build two brick wall model, one with agricultural waste bricks (AWB); selected from the best of three types of agricultural waste and one with control brick (CB). The small masonry wall model with a height (1.0 m), width (0.215 m) and length (1.0 m) was built.

1.5 Significance of the study

This study will be a significant endeavor in promoting green technology in developing a friendly and sustainable product. Recycling of the RH, WT and CC by incorporating them into building materials is such a practical solution to a waste disposal and energy saving material problem. Moreover, utilization of RH, WT and CC that are generated from most agro-based industries is currently very rewarding. The anxiety caused by enormous waste production, resource preservation and material cost has focused the attention on the reuse of the waste. In particular, the purpose of this study is to determine the potential and feasibility of fired clay bricks that are incorporated with RH, CC and WT in increasing the added value of these products, especially in building materials as well as to get the thermal comfort in the building. Thus, an experimental investigation was conducted to explore the physical and mechanical properties of fired clay bricks by using RH, WT and CC.

1.6 Thesis Outline

This thesis is divided into five chapters. In Chapter 1, a general introduction to the research background, problem statement, objectives of the study, scope of the study and significant of the study were discussed. The literature review in Chapter 2 discusses the behaviour and characteristics of clay as the base material for clay brick. Reviews on RH, CC and WT used in brick manufacturing process are also discussed to provide better understanding about the test carried out and the pattern of result. Findings from previous researchers in waste material used and model testing attempted are also presented at the end of this chapter. Chapter 3 consists of experimental details of the study. All materials include clay, RH, CC and WT was discussed in detail. Proportion of clay soil, RH, CC and WT used also been discussed clearly. Brick manufacturing process had been discussed in details. The construction of a small masonry wall and the surface temperature test was described and discussed. Chapter 4 presents results and discussions of the material characterization test, geotechnical test, compressive strength test, water absorption test, thermal conductivity test and surface temperature test. Chapter 5 presents the conclusions of this study based on the analysis and findings from the experimental results and discussion. Recommendations for future studies are also included.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 deliberates and discusses usage of these waste materials in brick production published by previous researchers. This chapter also discusses the potential of RH, WT and CC in brick manufacturing. In addition, characteristics of the raw materials used and the basic properties of brick are also discussed. The concept of using natural fibers is not new in the construction industry, as the utilization of fibers in materials and construction can be traced back to many centuries ago. During the Egyptian times, straws or horsehairs were added to mud bricks, while straw mats were used as reinforcements in early Chinese and Japanese housing construction (Li, 2002). The application of natural fibers has been widely used in cement composites and earth blocks as construction materials for many years in developing countries due to the availability and low cost of fibers (Ismail and Yaacob, 2011).

2.2 Brick dimension

Dimension of the brick is by referring to BS 3921: 1985. Table 2.1 which extracted from BS 3921: 1985 shows the dimension and size of the clay brick.

Table 2.1: Size of bricks (BS 3921: 1985)

Coordinating Size			Work Size		
Length (mm)	Width (mm)	Height (mm)	Length (mm)	Width (mm)	Height (mm)
225	112.5	75	215	102.5	65

By referring to the standard, the work size of clay brick had been set up to 215 mm x 102.5 mm x 65 mm as shown in Figure 2.1 while the coordinating size of clay brick had been set up to 225 mm x 112.5 mm x 75 mm. Work size means the actual size of the brick that should conform within specified permissible deviation while coordinating size means the size of coordinating space allocated to a brick including allowances for joints and tolerance.

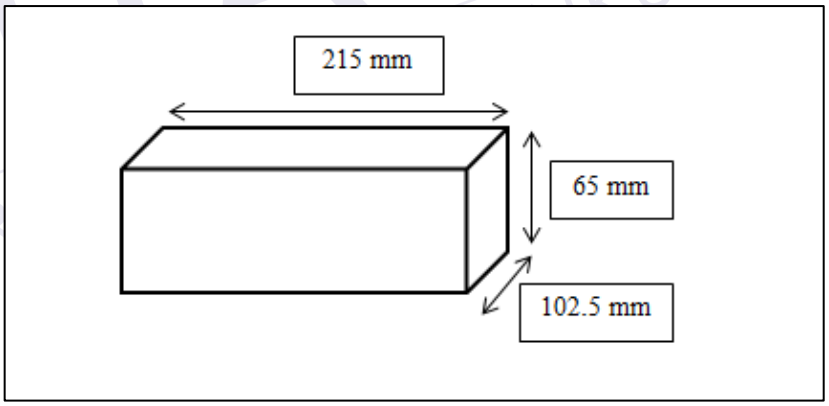

Figure 2.1: Brick dimension (BS 3921: 1985)

2.3 Engineering properties of fired clay bricks

Different mixing percentage in the brick manufacturing will affect the engineering properties of the bricks. As for the example, the density of the bricks will influence the

engineering properties of bricks. Engineering properties that are evaluated in this study included the compressive strength, water absorption and thermal conductivity test.

2.4.1 Compressive strength

In engineering, compressive strength of clay bricks is one of the factors that determine the properties of the end products. Compressive strength can be seen through the different use of compression molding of the maximum hydraulic pressure (Yap, 2010). Additional materials used as an additive effect the compressive strength of the bricks. This is because these additives were improving the soil structure. Compressive strength test is important to determine the durability of bricks in building construction. Table 2.2 shows the standard for compressive strength requirement based on BS 3921: 1985. This study used a reference value of more than 5 N/mm^2 which is on other type of bricks.

Table 2.2: Compressive strength requirement (BS 3921:1985)

Type of Brick	Compressive Strength (N/mm^2)
Engineering A	>70
Engineering B	>50
Damp proof course 1	>5
Damp proof course 2	>5
Others	>5

2.4.2 Water absorption

Brick is a material that has the characteristics of fine pores that can absorb water. Absorption occurs when water seeps into the pores of the brick body. Water absorption is an indicator for the durability of bricks effects from the exposure to weather and moisture. Table 2.3 shows the standard used for water absorption according to BS 3921: 1985. This study used a brick type of others as the reference value which is there is no limit but sets a maximum limit of 15% according to MS 76: 1972 Part 2.

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